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The Particle Accelerator

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The wind was flowing to the north, and so was spring.

Out of its winter hiding places life was emerging. The land was turning from black and white into colour. Mammals, reptiles, and insects were unthawing from a winter's sleep and moving about. The air was thick with seeds searching for places to bloom. These seeds were not just those sprayed from plants, but also those riding inside the reproductive organs of birds.

Upon the northward wind, and upon the smaller wind each bird received from the wings of the bird before it in the V formation, a flock of swans was heading for their breeding grounds in the north of Canada. Feeling the same primordial force that stirred every form of life into its own version of spring, the swans had left their winter home on Chesapeake Bay. They had risen over the Appalachian Mountains and swung along the southern rim of the Great Lakes, heading across the American midwest and almost to Alaska in a journey of some two thousand miles. Right now the swans were crossing the farmland around Lake Michigan. The horizon was approaching the sun and beginning to pull across it the atmospheric prism, colouring the sky and undersides of clouds. Yet though the light was ending, for the swans this was still early in another day's flight.

Their long necks stretched out straight before them, their legs tucked carefully against their tail for streamlining, the forty swans chopped the air with their wings, with a blending of power and grace. Except for their beaks and feet, the swans were as white as if they were clouds that had condensed right through the state of water and into the state of life.

The light faded quickly when the swans flew into the dark, brewing clouds of a thunderstorm. Flying at several thousand feet high, they were caught in the powerful currents inside the stormclouds, which heaved them up and down, jerked them about, and skewed their formation. Rain pounded against them, and thunder roared through them. Calling out to one another in their high-pitched voices, the swans struggled to stay together and to escape the currents. They rapidly descended through the storm. When they were close enough to the ground to see through the jungle of rain, they searched for a place to land. Soon they saw what seemed to be a giant circle on the ground, and amid the land inside it was a lake.

The swans skimmed over the trees beside the lake and slowly descended, holding their wings to brake. As they neared the water they lowered their feet and spread wide their webbed toes. They swung their bodies vertical, pointing their tails downward and their feet forward. As they plunged their feet into the water, the energy accumulated by forty pairs of beating wings was translated into forty large wakes spreading behind the swans sliding across the water.

In the control room at the edge of the accelerator, which formed a circle four miles round in the Illinois countryside, scientists prepared for another probe into the secrets of the universe. The Fermilab accelerator, one of the world's most powerful, would generate a stream of particles, boost them to enormous speed, and then aim them at a metal plate.

The energy of impact would shatter the target atoms into their constituent particles and create new particles as well. These particles would spray through a bubble chamber, which contained a special liquid that would turn into a trail of bubbles where a particle passed through. From these wakes the scientists could determine a particle's size, speed, charge, and spin, and perhaps glimpse a little deeper into the structure of matter.

The scientists moved down the long control panels, pushing switches and checking lights and gauges to bring every part of the complex system into readiness. They readied the power generators to fire off the equivalent of many lightning bolts. They readied electrodes to apply that energy onto the particles. They activated long chains of powerful magnets to guide the particles' flight. They made sure the vacuum pipes were empty and the superconductors -450.ø.F degrees cold. They brought the network of sensors and computers to life, and told them how to run this experiment. They checked that the target was in place and that the bubble chamber, cameras, particle counters and other devices were ready to detect the results. When the scientists saw that each of hundreds of systems and subsystems was set to work at exactly the right power and precision and in microsecond synchronization with one another, the director gave the signal to begin.

In the lake in the middle of the accelerator, forty swans glided across the water, drawing wakes across the ripples drawn by the wind and erasing some of the tiny rings spreading out from the thousands of raindrops striking the water every moment. In the distance the clouds struck the ground more powerfully with a lightning bolt, sending equally powerful ripples spreading through the air for miles. The swans moved towards the shore and drifted along it until they found a shallow cove that offered both shelter and food. While they waited for the storm to pass, the swans would store up more energy to turn into wind.

The swans poked their heads into the water and tugged small plants out of the mud, or skimmed their beaks along the water's surface to collect algae. With a mouth full of food they raised their necks and swallowed. They curled their necks down again and dipped their beaks to suck in a mouthful of water, a few atoms of which had just been part of the massive, turbulent power of the storm and swirled down from the sky, and which now swirled down into a more sophisticated flow.

Power surged through the Cockcroft Walton generator and set flowing a stream of hydrogen atoms, the basic atom of the universe, forged in the first moments of the Big Bang, the atom from which all other matter has been built in the course of cosmic evolution. To the single proton and electron of the hydrogen atom, the generator added another electron to make the atoms electrically charged so that magnetic fields could grip them. Boosting the atoms to an energy of 750,000 electron volts, the generator fired them into the next stage of the process, the 500 feet long and straight Linear Accelerator.

The atoms flowed through the narrow vacuum pipe surrounded by huge electromagnets, which kept the atoms focused in the middle of the pipe. Every foot or so an electrode poured energy into the vacuum pipe, setting up an electrical surf wave on which the atoms rode and gained speed and energy to 200 million electron volts. In only an instant the atoms had raced through this throat and into the third of five stages of acceleration.

The water molecules, which were made of two hydrogen atoms and one oxygen atom, trickled down the throat of the swan and into the stomach. The water flowed into a soup of algae, leaves, stems, and roots, which were slowly being dissolved so their matter and energy could be absorbed into the swan.

The leaves were packed with photons that had recently arrived from the sun, where they had taken part in pushing hydrogen atoms up the first step into higher order. From that hydrogen storm the photons had come to a world where matter had journeyed far indeed into higher order, and the photons were absorbed into that order to help push it onward.

The plants also contained particles absorbed from the earth, particles that had been cemented in rocks for a billion years and then torn loose to sit in other crude masses for ages, particles that had been eroded from a dozen mountains, been volleyed in the wind, and been swept down a million rivers to the sea, momentarily merging with that other crude, turbulent flow on the planet, the flowing of water. This force too had been siphoned into the swan's stomach, and together the crudeness of sun, land, and water was being molded into the shape of a swan.

Many miles away another kind of leaves fell into a stomach. Time and the earth had changed these leaves from soft green into hard black, but they were still packed with particles they had absorbed from the sun. In this metal stomach the leaves were digested by fire and they released their sunlight. Energy that might have powered the flight of pterodactyls now raced through power lines across the countryside and into the Booster Accelerator, a circular machine 500 feet in diameter, where it stripped the racing atoms of their electrons and swept the remaining protons around and around, transferring to them an energy of eight billion electron volts. Pushed by the combined effort of trillions of ancient cells, the protons raced into the Main Accelerator.

Tied inside molecules of water and food, the protons flowed through the pores of the stomach and intestines and into the bloodstream. They were swept through the tree of veins and into the heart, where a steady electrical pulse was magnified into a steady pulsing of flesh, sending the protons racing throughout the body. They swept into the lungs and helped capture a tiny portion of Earth's crudely surging air to make surge the weather of bodies. The protons flowed into cells and joined the waltz of molecules, helping to carry giant molecules back and forth, helping to break them apart and bond them into larger molecules, helping DNA unfurl and copy itself, helping cells grow and split into more cells. The protons became part of dozens of types of molecules performing dozens of kinds of tasks in dozens of types of cells. They became the firmness of bone and the softness of eyes, they became the power and beauty of a swan's wing. And when the protons joined the pulsing energies and particles of the brain, they looked out, through eyes where light caught by leaves now energized the catching of light in optical leaves, and saw the beauty of a swan's wing, saw forty swans gliding together on the waters of a lake, saw the surface of the lake rippling to the breeze and the raindrops and the light of the disappearing sun, saw the prairie and trees and human buildings around the lake, and saw the clouds beginning to part and reveal the deep lights and spaces of the universe.

The Main Accelerator applied far more power to the protons, sweeping them around the four mile underground track until they approached the speed of light and were circling some 50,000 times every second. At the precise microinstant in each lap, the accelerator poured a wave of energy into the slice of outer space inside the vacuum pipe, and it also poured energy through the surrounding magnets to keep the protons focused in the center of the pipe and to turn them as the pipe turned. The Main Accelerator contained two layers one atop the other, and when the top layer had accelerated the protons to 150 billion electron volts, it fired them into the lower layer.

When the rain stopped, the swans vigorously shook every part of their bodies to throw off water and fluff their feathers. Accelerating air through their long necks to call out to one another, they drifted into the center of the lake. Swans do not easily get airborne and need a long runway, perhaps one hundred feet.

The swans began paddling hard with their feet and surged forward. They spread their wings and thrashed the air, thrashed once a second and then faster, lifting themselves out of the water until they were running upon it, their feet slapping it with force enough to raise splashes a foot high. The energy of each rowing of wings rippled through their bodies and caused their tails to flap and their outstretched necks to undulate. Side by side, half a wing-span between them, the forty swans raced across the water, and then they were free of it and slowly gained altitude and speed.

The swans crossed the shoreline, crystallized into a V formation, and began swinging in a large circle. Swans usually migrate by night and can use the constellations to find their way, but under these clouds they would have to rely on Earth's magnetic field. They flew a circle four miles long around the lake, sensing out the direction and strength of the electromagnetic waves flowing through the sky. Inside them, protons swarmed to calculate the direction home, the direction to that one marsh or lake shore where the swans were born, and to accelerate themselves to it.

Speeding directly beneath the circling swans were other protons, and they too were migrating back to a place they hadn't been in a long time. Theirs was a much vaster migration, reaching across billions of lightyears of space and across fifteen billion years of time to where the protons were born, to where the cosmic egg cracked open with a big bang and the universe emerged.

In the course of evolution on Earth, the force that began as a feeble flowing of particles inside a cell had grown increasingly sophisticated and powerful. Life enhanced that flowing by merging it with the flow of light from the sun. Cells expanded into many-celled bodies, with particles, energy, and information flowing throughout those bodies and between them. Bodies developed ingenious ways of moving themselves about. In brains this flowing quickened itself into knowing, until humans were wondering what all the flowings of Earth and sky were made of and where they had come from, and humans built huge instruments to find out. With this particle accelerator, this circle like a hugely magnified cell with a lake as nucleus, the cells of Earth had hugely magnified their skill at moving particles, magnified it into the power and precision necessary to boost particles into a re-creation of the Big Bang.

The protons raced into the lower ring of the Main Accelerator, into the powerful electromagnetic grip of a chain of one thousand super-conducting magnets, which a vast refrigeration system worked to keep at a temperature as cold as space so electric currents could flow easily through them. The protons were pushed ever faster by continuing pulses of energy, pulses that were really an amplification of the human brainwaves that formed ultimate questions and conceived of this accelerator. From these waves the protons gained an energy of one trillion electron volts. Then the magnets snapped the protons out of their circle and raced them down a long straight track, at the end of which all the energy of their motion was instantly turned into an energy of impact that matter hadn't reached since the first microsecond of the Big Bang. The protons smashed into the target atoms and overwhelmed the energy that held the atoms together, sending their pieces spraying apart to swerve and spin according to their varied natures. This energy of impact was so intense that it not only broke particles loose but also transformed itself into new particles too energetic to exist in normal conditions, particles which flashed through the bubble chamber for an instant and disintegrated into other particles and back into energy.

In only an instant this explosion, this glimmer of the Big Bang, was over. Compared to the scale of the real Big Bang, this explosion was tiny indeed. Yet when the products of this collision and thousands like it flowed through the bubble chamber inside the human skull, these collisions would create again the whole Big Bang and all the matter and energy in the universe.

As the swans broke form their circle and headed north, they flew directly over the timewarp to the Big Bang, over the particles speeding and colliding in the way every particle in their bodies had done so long ago. While the matter in the accelerator was being stripped naked to reveal its deepest structure, its most basic bonds and forces, the swans were clothed in fifteen billion years of order and ability. Atop the gluons binding them together, they were also bound by love. Atop the physical constants that gave all their particles a similar form, they now carried DNA that gave them the similar form of a swan. Atop the electromagnetic force that kept their electrons flowing, they now flowed out of fierce determination to turn on their DNA and let the swans coiled within it

materialize. Like particles in the Big Bang, the swan's acceleration would lead to their splitting apart, but the swans would split more gently by squeezing eggs out of their bodies.

The swans climbed hundreds of feet and might have risen for thousands if not for the clouds. Steadily waving their wings, they cruised at about thirty miles an hour, and rode faster when the wind surged.

As they moved north, the swans passed over land they had last seen in the autumn. Then the land had been dying, the grasses shrivelling up and the trees turning from green to red as they bled their life away, rotting from plump bodies into skeletons. Insects, reptiles, birds, and mammals had been disappearing into sleep, migration, or death.

Now this land was erupting with life. In the prairies, in the woods, in the farmer's fields, in the city parks and backyard gardens, in the waters of lakes and rivers, seeds were switching on the plants were sucking in soil, water, air, and sun and spinning them into cells. Plants of thousands of shapes fit together like jigsaw pieces to form a solid green, a Mondrian picture of the vigour of life. Here and there amid the green, the neon signs of flowers advertised their particular forms of life. The plants were being transformed into the tens of thousands of kinds of insects swarming among them. Everywhere eggs were hatching. Animals were roaming on the ground, beneath it, and through trees. The streams and lakes were flowing into the veins of fish and, with fins, signing their new name upon the water's scribbling surface. In the air beneath them and alongside them the swans passed many other birds, some of them also in large formations migrating home, all of them inhaling the wind to make it blow them along from within.

On their northward journey the swans were seeing a tide of life sweeping across a whole continent. They were seeing the surface of a planet where something special had happened.

As the swans flew on, they left the clouds behind and entered a sky of thousands of lights. Among those lights were the other planets of the solar system, none of which were anything like Earth. The stars' surfaces were even more chaotic. As large as the life of Earth might seem to the swans as they flew above it, that life was very small and rare in the universe. In the vastness of space, all the stars and planets were but tiny particles, among which one blue particle's surface had begun flowing in tiny but rich patterns.

The swans flew on through the night, calling to one another to bond their formation. In the darkness below they saw the lights of human cities and highways, and in the darkness above they watched the steadier constellations of stars, by which they plotted their course. Among those thousands of points of light, there was one light, near the horizon on their right, that humans officially called NGC 6618, and which was also informally known as the Swan Nebula. The nebula's shape, a white tapering body with a stubby neck rising from one end and expanding into a head and beak, with even a dark patch for an eye, reminded humans of a swan at rest.

Or perhaps a swan sitting on a nest.

The Swan Nebula was a huge cloud of gas and dust condensing to form stars. Perhaps the blastwave of a supernova had swept through space like a warm front and started the gas and dust condensing, or perhaps the weather of space had more gradually gathered matter enough to condense upon its own gravity. Now the nebula was brewing like a thundercloud, full of massive currents of matter and energy. Some of those currents were spiralling inward and in their center thickening into a star. When the stars ignited they poured light through the cloud and made it glow. The outward pressure of the light stopped the nebula from condensing further and began to disperse it.

When the Swan drifted away, she would leave a batch of eggs, the planets solidified from her body. For ages those planets would incubate in the warmth of their stars, and one day one of them might hatch. From that egg would fly millions of swans, their white feathers a condensation of that white nebula, their convoluted brains a knot tied from those clouds. From that egg would fly, swim, crawl, hop, walk, jump, run, float, waddle, slide, and march innumerable forms of life.

The swan offspring of that nebula would flow back and forth across their planet in seasonal migrations. Each spring they would feel a rising impulse to return to the place of their birth. They would cross bays and mountains, prairies and lakes, flying through storms and crystal skies, through day and night, guiding by scents and landscapes, magnetic fields and stars. At the end of their flight they would give birth to new swans, who would carry on that ancient migration.

Indeed, the swans would have inherited this migration from their ultimate parent, the Swan Nebula itself. She too had completed a long migration to reach the place where she could lay her eggs. She had flown all the way across the universe, a migration that began in the Big Bang. This was a migration not just in distance, but also in form. This nebula had travelled through all the phases of cosmic evolution, from the making of quarks to the making of galaxies, through each level of particle building in the Big Bang and atom building in stars. The nebula was still migrating, heading into the next phases of cosmic evolution, into the building of solar systems, of planets, moons, comets, and asteroids; into the building of complex geologies, of ever-shifting tectonic plates, mountain ranges, volcanoes, oceans, deserts, and arctic ice; into the building of weather systems, from the empty breezes of some planets to the roaring, kaleidoscopic bands and spirals of planets like Jupiter. And then the nebula would flow into life.

The swans born from that nebula, and the swans and all the life hatched from egg Earth, were the culmination of a great flowing of matter through fifteen billion years, a flowing begun by the Big Bang. The Big Bang had sent stars and planets racing through space like protons in a particle accelerator. The Big Bang had begun this acceleration with real protons and other basic particles, but as they flowed onward they began flowing in more elaborate patterns and assuming more complex forms, becoming stars and planets, lakes and thunderstorms, leaves and the human brain. The Big Bang accelerated raw particles into the grace and love of migrating swans. The Big Bang accelerated particles until they formed an image of the Big Bang accelerating nothing into everything.
